High Frequency Bottom Interaction Acoustics in the Atlantic Natural Laboratory

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LONG-TERM GOAL

The long term objectives of this project are: 1) to develop a numerical technique capable of predicting the low frequency acoustic wave field scattered from geologically realistic models of the bottom/sub-bottom environment; 2) to isolate from the scattering models the physical mechanisms which dominate the long-range reverberation from the seafloor; and 3) to characterize the variations in bottom topography and sub-bottom properties that control the scattering of low frequency acoustic waves.

OBJECTIVES

Our goal is to identify the geological features on the seafloor that are responsible for strong, low grazing angle, monostatic, backscatter and to determine the physical scattering processes associated with these geological features.

APPROACH

We have chosen initially to look at the match filtered traces of the broadband LFM sweeps from the Acoustic Reverberation SRP 1993 acoustics cruise. The method and results are discussed in detail by Greaves and Stephen (1997). The modeling is constrained by the geological data sets acquired in and around Site ‘A’. Based on the geological data sets we prepare models of elastic parameters and density that we can use in our Numerical Scattering Chamber (NSC). The NSC predicts the monostatic backscatter that we would expect from a given model and this in turn is compared with the actual acoustic returns from the geological area.

WORK COMPLETED

This project was the thesis research for Bob Greaves. Bob successfully defended his thesis in June 1998 (Greaves, 1998). The thesis consisted of five main sections. The first section was the analysis of the broadband LFM sweeps from the Acoustic Reverberation SRP 1993 acoustics cruise (Greaves and Stephen, 1997). The second section was a thorough synthesis of all of the geological data sets acquired in and around ARSRP Site ’A’ and a number of seafloor models were constructed based on the geological descriptions (Greaves and Stephen, in prep c). The third section addressed a study of idealized canonical models of monostatic backscatter from rough and laterally heterogeneous seafloors (Greaves and Stephen, submitted). A large suite of models addressing specific features of the seafloor were run. The fourth section studied the effects of large scale slope and large scale average sub-bottom velocity (Greaves and Stephen, in prep a). The fifth section used the modeling results to construct a

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methodology for inferring bottom characteristics from the monostatic backscatter data and applied this methodology to an interpretation of the 1993 acoustics data (Greaves and Stephen, in prep b).

RESULTS

Greaves' thesis has shown that the backscattered signals observed in monostatic reverberation experiments are caused by scattering from wavelength-scale seafloor and sub-seafloor variations in the velocity and density. This is an important result, because much of the previous interpretation of acoustic reverberation data has been in terms of large-scale seafloor characteristics that are much larger than the wavelengts of the insonifying field. It was shown in this thesis that large-scale features, in particular high-standing ridges with steep slopes, will generate the expected high backscatter intensities. However, the source of this scattering is not the slope but the exposed basaltic rough seafloor that is found on these ridge flanks. The large-scale slope acts to enhance the scattering intensity by increasing the local grazing angle, but the slope is not the "source" of the scattering. It is also clear from the results of this study that similar strong scattering can be generated in relatively low-slope areas if the seafloor is an exposed and very rough basaltic bottom. Such seafloor is expected in regions of young oceanic crust where sediment accumulation is negligible.

It has been shown that scattering intensity is clearly a function of most of the seafloor characteristics included in this study, for example, average subseafloor velocity and density, large-scale slope, wavelength-scale rms amplitude and seafloor and subseafloor heterogeneity. Some parameters, such as subseafloor velocity gradients and individual faults have no discernible effects on scattering. In general, the sensitivity of backscattering to the former parameters is such that they can each account for much of the signal variation in reverberation data. However, the apparent functional relationships between these parameters and the backscattered signals is non-linear in each case. This leads to the conclusion that a unique interpretation of monostatic reverberation data may not be possible.

Another important conclusion is that although subseafloor volume heterogeneity at wavelength scales can produce a strong backscatter signal if the seafloor is very smooth (for example, a smooth sediment bottom with lateral heterogeneity), when the seafloor is rough the effect of volume heteroegeneity on the backscattering cannot be distinguished from the seafloor scattering (Figure 1). In general, volume scattering effects, observed in the water column, are primarily generated by scattering from heterogeneity that occurs just below the seafloor, which is comparable to scattering from seafloor roughness.

This study has yielded a greater understanding of the true complexity of the scattered signal that is observed in monostatic reverberation experiments. Finite-difference modeling has proven to be a very effective technique for determining the sensitivity of scattering to variations in geological models. It is important to keep in mind that sound scattered from the earth does, in fact, carry information about the geological properties of the earth, even though interpreting such signals is a very complex process.

IMPACT ON SCIENCE AND TECHNOLOGY

One product of this study is a test of Lambert's Law for low angle backscatter from the seafloor. Although Lambert's Law may work to explain observations, other functional relationships could work just as well. By considering the different geological provinces of the seafloor in more detail we provide a more accurate representation of back scattering than is currently being used in the fleet and at some Navy labs. The techniques developed in this work and the insights gained into scattering mechanisms

will apply to a broad range of environments (including deep and shallow water and sedimentary and igneous bottoms) and over a broad range of frequencies (from 10Hz to over 100kHz).

TRANSITIONS

RELATED PROJECTS

REFERENCES AND PUBLICATIONS

Greaves, R.J. (1998) Seismic scattering of low-grazing-angle acoustic waves incident on the seafloor.," PhD Thesis, Massachusetts Institute of Technology and Woods Hole Oceanographic Institution Joint Program in Oceanography.

Greaves, R.J. and Stephen, R.A. (**1997**). "Seafloor acoustic backscattering from different geological provinces in the Atlantic Natural Laboratory," J. Acoust. Soc. Am.

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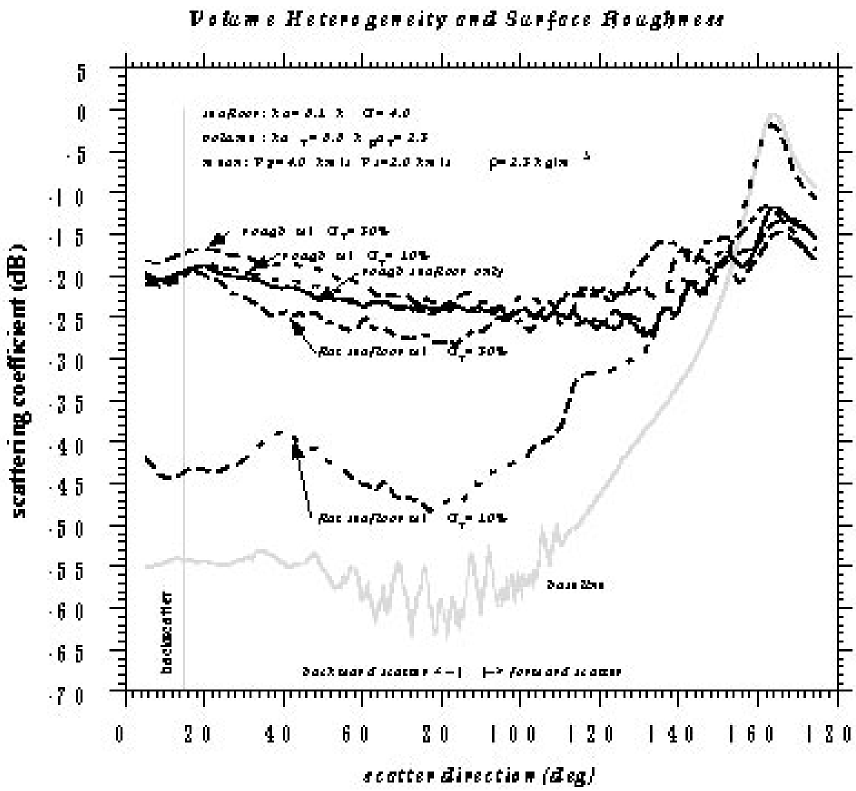

Figure 1: Scattering coefficient is plotted as a function of scattering angle for a range of models representing rough and laterally heterogeneous basaltic seafloors. The incident field is a Gaussian beam at 15° grazing angle. The specular reflection is at 175° and monostatic backscatter occurs at 15°. The light gray line is a baseline solution for a flat, laterally homogeneous seafloor and shows the specular reflection and the numerical noise floor. Just above this line, with a monostatic level of about -43dB is a flat sea floor with 10% variability in the sub-bottom and a normalized correlation length of 6.6. The same flat seafloor model with 50% volume heterogeneity gives monostatic backscatter at about -20dB. Also shown are three curves for a rough seafloor with a normalized heigh variability of 4.0 and a normalized correlation length of 6.1. The three rough seafloor models differ in the extent of sub-bottom heterogeneity but they all give comparable monostatic backscatter values around -20dB. (Figure from Greaves (1998).)